General Plastics Manufacturing
Company

Polyurethane Foam and Sand Barriers Extend Munitions Igloo Capacity

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Introduction

Safe high-explosive mass-storage methods usually rely on a simple combination of earth and concrete barriers, combined with sufficient distance between loads, to avoid accidental conflagration. Established Net Explosive Weight (**NEW**) equivalencies and Quantity-Distance (**Q-D**) storage standards allow conventional 40' by 80' earth-covered magazines (or: "igloos") a maximum of 425 pounds NEW storage per unit. With each unit separated from others by the required distances, an accidental explosion could be limited to a single magazine, without initiating other explosions nearby.

However, using this storage method at Air National Guard installations is made complex by a need to co-locate with civilian aviation activities. Often, meeting Q-D safety requirements is difficult, or impossible. At the same time, it may be unworkable to keep adequate stores of ordnance items nearby to meet Guard-unit mission requirements, while maintaining adequate safety.

Expanding urbanization around formerly isolated bases contributes added safety and security concerns, sometimes forcing use of inconveniently remote storage magazines to support unit-mission objectives. Magazine-availability constraints resulting from continued downsizing of military facilities and functions might make impractical the storage of ammunition and explosives in other locations.

Explosive and ordnance researchers and manufacturers encounter these identical problems and concerns. Both military and civilian facilities often need a convenient way to expand magazine storage capacity to meet schedules, lower costs, and improve efficiency. The ideal solution lay in an easily constructed blast wall system, which, when added to the interior of an igloo, shields and segregates multiple explosive loads while maintaining magazine safety at low cost.

Through a combination of materials engineering, physical property and flammability testing, and blast-performance modeling, ANG and General Plastics Manufacturing Company personnel cooperated to develop a flame-retardant polyurethane foam and sand blast- wall system meeting these multiple needs.

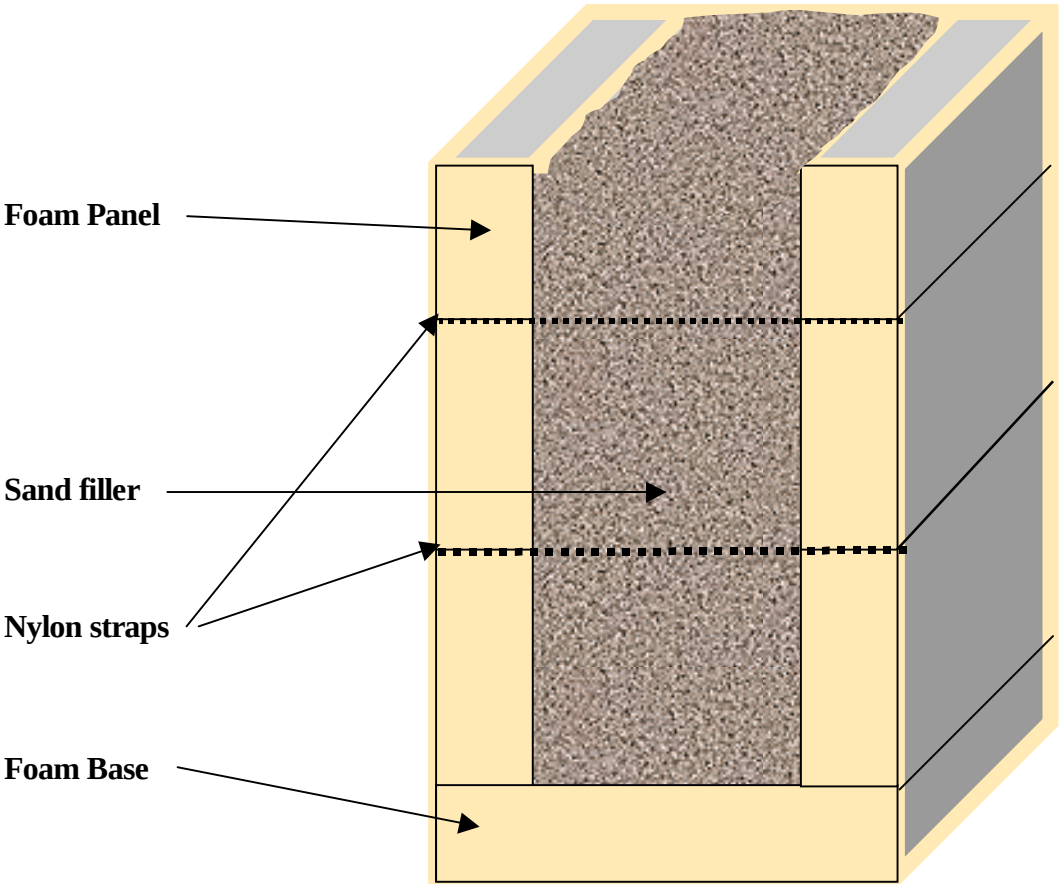
Evolution of the System

In 1994, the Vermont Air National Guard approached General Plastics Manufacturing Company for a quotation on a "Foam Barricade System-Sand Containment Storage" project. The design of the system called for a combination of extruded polystyrene foam sheet and sand, constructed around the characteristics and sheet-sizes of the polystyrene foam material, easily obtained from a local foam distributor. However, the local distributor was not interested in the fabrication needed to complete the system.

CMSGT Ken Gragg at the Air National Guard base in Burlington, Vermont devised this system to allow better use of the limited space available to store ordnance and explosives at his facility. He gained DDESB approval for this cost-effective system as an alternative to building additional magazine space, for **Explosive Hazard Classification/Division types 1.1**

and **1.4**. For specifically approved items, this design allowed an **eight-fold increase** in allowable NEW storage in his facility.

Vermont ANG
Wall System Cross-section



General Plastics Manufacturing Company specializes in polyurethane foams, and products made from foam materials. While General Plastics could purchase the styrene foam and fabricate the system as specified, we felt there were compelling reasons for looking at an alternative material.

To make our case, we obtained Styrofoam® *High Load 115* polystyrene foam sheets from a local distributor for comparative testing against General Plastics' *LAST-A-FOAM® FR-3705* flame-retardant polyether polyurethane foam. It appeared relevant to test both materials for their physical strength properties and for their resistance to combustion, which seemed appropriate in the application. The results follow in the accompanying table.

Comparison Chart: *High Load 115* to *FR-3705*

Foam Property	Styrofoam® *High Load 115*	LAST-A-FOAM® *FR-3705*
Foam Density	**3.41 lbs/cu. ft.**	**5.14 lbs/ cu. ft**
Compressive Strength (ASTM D-1621)		
Parallel to Foam Rise	**70 psi**	**150 psi**
Perpendicular to Foam Rise	**35 psi**	**115 psi**
Flammability Resistance Corner-burn test	**Completely consumed, flaming pool of molten resin**	**Mildly charred, 98% mass retained**
Solvent Resistance petroleum vapors, chemical cleaners, solvents	**Poor**	**Excellent**

LAST-A-FOAM® FR-3705 performed much more favorably than the Styrofoam® product in every area. The comparative test results for *FR-3705* in the areas of flammability and solvent resistance revealed some significant advantages over Styrofoam® *High Load 115*.

Polystyrenes exhibit poor solvent resistance, especially to petroleum liquids and vapors. We saw little advantage in a wall system that might be degrade or collapse due to a solvent spill. At the same time, flammability testing showed the polystyrene foam to be roughly equivalent to gasoline in solid form. We felt the burning liquid pool formed by the melted foam was a particular hazard, since it could flow and run towards other flammable materials.

In contrast, the *FR-3705* would not support combustion after fire consumed the fuel source used in the test. In fact, the foam material that burned formed an intumescent char layer, which insulated the rest of the board from further degradation and mass loss. As there is no combustible residue remaining in the char layer, there was no smoldering material present to re-ignite later. Also, the solvent resistance of polyurethane is well recognized, and the *FR-3705* has a closed-cell structure that makes it all the more resistant to solvent penetration and wicking.

Once in place, *FR-3705* needs no maintenance. Being a fully reacted polyurethane material, *FR-3705* is inert, is unaffected by most chemicals and solvents, and dimensionally and chemically stable. Ultraviolet light exposure causes surface discoloration of the foam, but is limited to only the surface exposed. Test samples of LAST-A-FOAM® materials have shown no change in physical properties, even after aging for 20+ years.

LAST-A-FOAM® *FR-3705* will withstand wide fluctuations in temperature, and has sufficient structural strength to withstand a limited amount of physical abuse. The foam offers no nourishment for insects or vermin, and contains no toxins to contaminate the igloo structure or its contents. *FR-3705* can be painted, if desired, but needs no protection to perform superbly in the igloo environment.

Finally, rigid foams are excellent impact absorbers. Because of our work with Sandia National Laboratories and others, we recognize a significant potential for foams in blast-effect mitigation. In a properly engineered system, each cell within the foam acts as an energy absorber as the explosive pressure wave hits it. As the wave contacts the foam, the force of the explosion is absorbed as foam cell-walls break down. This effect can absorb vast amounts of explosive energy.

The First Installation: "Just add sand…."

General Plastics was supplied design information by the Vermont ANG, so that the parts could be produced in our factory. The system was shipped complete (less sand) from General Plastics with pre-cut, tongue-and-grooved foam panels. Sheets were stacked horizontally with staggered joints, to withstand sand pressure. The design called for nylon straps or strapping tape) to hold the foam sheets together.

As the original design called for 16-inch wide panels, we fabricated the system as designed with the thought we might seek to make improvements later through making larger panels, to reduce part-count and bond-joint numbers. This would also reduce costs through better material use and less labor to fabricate.

We also supplied a detailed installation parts list so that assemblers could identify the various system components and install them in proper sequence, and spacers to help keep wall panels correctly spaced before they were filled with sand.

Available personnel at the Burlington ANG facility performed the installation of the first system. With no special training or instruction, they were able to complete the installation in 4 days using four people. This installation has been in-place since 1994.

Benefits to Vermont ANG

The Vermont Air National Guard gained these primary benefits from retrofitting this polyurethane foam and sand barrier wall system to their earth-covered magazine (ECM):

- **Easier Access to Needed Stores:**

  Air National Guard units are usually co-located on joint-use airfields. They are usually unable to support the 1,250-foot clear-zone requirements for larger quantities of explosives, limiting storage at their facility. This improvement allowed more material to be stored close at-hand.

- **Reduced Clear-Zone Requirements:**

  Up to 425 pounds NEW of Hazard Class/Division 1.1 is approved per cubicle. In addition, the igloo can be sited for reduced Q-D criteria of 700 feet in front, and 250 feet to the sides and rear. This means that a 40-foot by 80-foot igloo can hold 3,400 pounds with this barrier system, instead of only 450 pounds without the barrier.

  It is also possible to place an igloo approved for 150 pounds NEW with a 500-foot front and 250-foot side/rear clear zone.

- **Better Space Utilization:**

  A 40-foot by 80-foot igloo has a volume of about 35,000 cubic feet. 11 cases of C-4 plastic explosive occupies approximately 12 cubic feet, and brings an igloo sited for a 450-pound maximum capacity to its explosive-weight limit.

- **Meets Munitions Compatibility Segregation Requirements:**

  The new system allows storage of several different munitions-compatibility's under the same roof.

- **Cost Effective Expansion of Existing Facility:**

  The Vermont ANG accomplished this capacity expansion at a materials cost of approximately $17,500.00. We have heard reports of new magazines of similar size costing between $100K to $250K, depending on local needs and conditions, environmental impact costs, and permit requirements.

  This cost figure does not take into account possible recurring savings derived from reduced trips to more remote storage areas, and the value of any security required to protect those areas.

Word of the success of the advantages of this system, plus the ease of installation, began to spread throughout the ANG community. Soon, General Plastics had requests from other ANG activities for quotations on additional system installations.

Since 1994, General Plastics built systems for these additional Air National Guard facilities:

Iowa ANG, Sioux City, IA

South Dakota ANG, Sioux Falls, SD

Massachusetts ANG

Montana ANG, Great Falls, MT

March AFB, California (in development)

Grissom AFB, Indiana (in development)

System Improvements

On review, as we processed new quotations and drafted additional system drawings, we made several improvements to system components to speed assembly. We also wanted to ease system fabrication, and reduce its cost.

We performed additional tests on the *LAST-A-FOAM® FR-3705* to determine its suitability for the application. Installation improvements included the use of knotted cord and plywood "buttons" to retain the wall against the weight of the sand ballast inside. We wanted a restraint that would stretch very little over time. We were concerned about the amount of stretch we might encounter in the cord itself, since this could lead to unacceptable "bowing" in the wall.

We had additional concerns about the cord pull-through resistance needed to withstand the sand pressure at the base of the wall. Under vibration, the sand-ballast material might behave like a liquid material, exerting "hydrostatic" pressure at the base of the wall. We calculated the pressure the sand could exert on the wall in this instance.

Using an Instron-type machine, we set up tests to simulate tensile forces pulling the knotted cord through the hole in the plywood button. Resistance was more than adequate to resist the sand-pressure, even with the sand considered as a liquid medium. We found, however, that most common cord fibers tended to stretch far beyond what would be acceptable in the application. We finally located a Kevlar®
fiber cord jacketed with a polyester braid for abrasion resistance and ease of handling, as our best low-stretch choice.

Finally, we needed a simple, yet strong bond-joint design, since we intended a simple system that would allow untrained workers to assemble the entire installation. We wanted a joint system that would be easy to fabricate, easy to assemble, and still give the wall the structural integrity needed to insure good performance. We wanted a joint that would also allow easy field-fabrication, since on-site modification was a likely prospect. We planned to use adhesive to complete the joint, to eliminate any metal fasteners, and provide additional structural integrity to the wall.

Testing revealed a spline-and-groove joint design worked best, and fit all our requirements. We determined a 15-pound per cubic foot density spline gave the best results for panel-strength. We specified a bull-nose profile for both the spline and the groove in the joint, to avoid stress-concentrations in a sharp 90° corner.

We also identified a commonly available construction adhesive to complete the joint, after testing several for bond-strength with the foam. Through our tests, we determined there could

be wide variation in the ultimate strength of different construction mastics. The brand and type selected exceeded our needs by a comfortable margin in all trials.

We made still more improvements as we went along:

- We have enlarged the panel size to 60" x 84" to reduce the number of joints in the wall and speed erection;

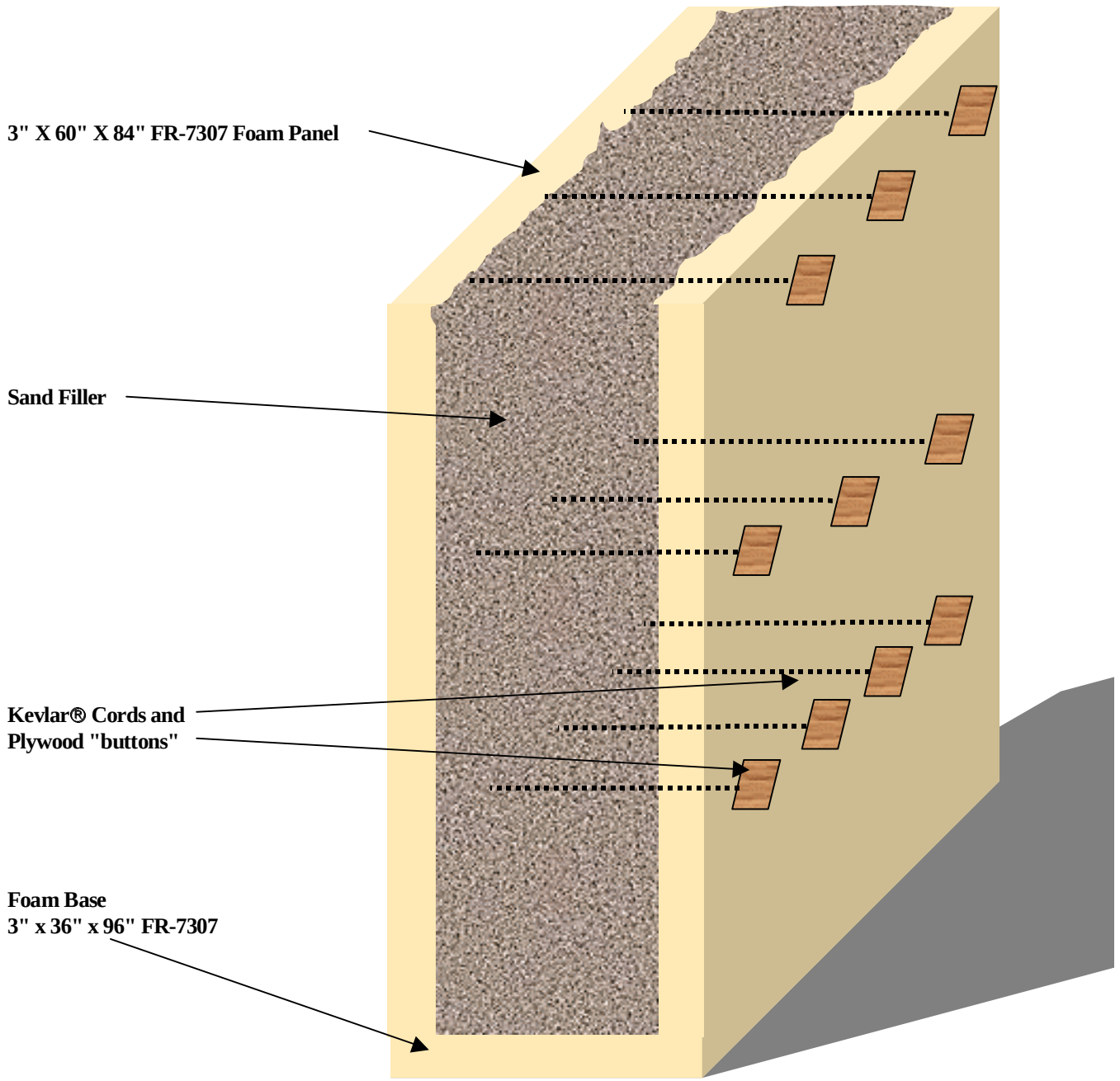
- We improved drawings and diagrams to make them more useful and easier to understand;

- We added steps to the internal "buttresses" used at the ends of wall sections; to make it more convenient for installers to exit the wall cavity as it is filling with sand.

- We improved the foam used in the wall system to make it even more flame-resistant than before, while also gaining some toughness. We believe this newer foam formulation, *LAST-A-FOAM® FR-7307,* offers additional fire safety. It contains an inorganic filler material that allows the foam to absorb greater amounts of heat energy before it begins to burn, and it extinguishes more quickly as well. Unlike other commercially available polyurethane foams, it will not form a "punk" that can smolder and re-ignite later.

Diagram of improved BLAST-TAMER Explosive Damping Blast-wall System

Incorporates all improvements made to system as of July 31, 1998



The Future

General Plastics hopes to build on the success of the **BLAST TAMER** system in other areas where the blast-mitigation properties of polyurethane foam and sand barriers might be useful.

We want to explore the true capabilities of the system. DDESB approval of the system rests on computer-model studies, using data derived from other testing. General Plastics would eagerly participate with any testing facility or program where we might be able to "piggyback" a cubicle system test onto another Explosive Hazard Class/Division 1.1 explosive event. General Plastics would gladly supply all needed **BLAST TAMER** materials at no charge for this effort.

We believe the enhanced flame resistance of **BLAST TAMER** would allow it to be used for other Explosive Hazard Class/Division categories where incendiary items are involved. This, too, could be determined with further testing, along with resistance to fragment and projectile damage.

Because of the environmental resistance of the materials used in **BLAST TAMER**, we see it useful in outdoor applications. With the addition of an exterior-grade paint coating, and rain protection for the sand filler, we see possible uses like:

Protective revetments around aircraft and/or motor vehicles
Temporary outdoor ammunition-storage
Anti-terrorist protection and bomb-squad operations
Moveable blast-walls in ammunition and explosive plants
Improved explosive storage safety in construction and mining operations

With modifications, there might be more uses for **BLAST TAMER** as portable personnel and materiel protection for military operations. Because this system has potential to be inexpensive and effective, while being easily transported and erected, rapid-reaction forces might find it useful when establishing a temporary base of operations. Sand and dirt are available all over the world; they would be the only materials needed locally.

Conclusions

- **A polyurethane foam and sand blast-wall system allows safe expansion of earth-covered magazine (ECM) capacity where Q-D storage requirements exceed available real estate.**

- **For specifically approved Explosion Hazard Class/Division 1.1 and 1.4 items, the BLAST TAMER system is an effective retrofit method for quickly adding up to eight times the original capacity to existing magazine structures.**

- **BLAST TAMER also allows reduced Q-D requirements for storage of approved items where space is very limited.**

- **BLAST TAMER is very cost-effective when compared to the cost of new magazine space.**

- **The BLAST TAMER foam and sand wall system offers significant benefits in durability, flame, and environmental resistance over other materials. It is inert, contains no metal parts, requires no maintenance, and is unaffected by the ECM environment.**

- **Engineered improvements to the BLAST TAMER system make installation quick and easy. No training or special skills are needed to accomplish system assembly. The system ships in kits with all materials needed for erection--just add sand.**

- **Significant additional applications may exist for modified versions of the BLAST TAMER system, especially in temporary-use situations or installations where frequent magazine layout change occurs.**

- **Live-fire testing will enable full evaluation of the protective levels available through use of the BLAST TAMER system.**

Attachment:

Drawing

ANG-DWG-96-001

Sample ECM floor plan using BLAST TAMER
Polyurethane foam and sand Wall System

40'X80' EARTH COVERED IGLOO FLOOR PLAN

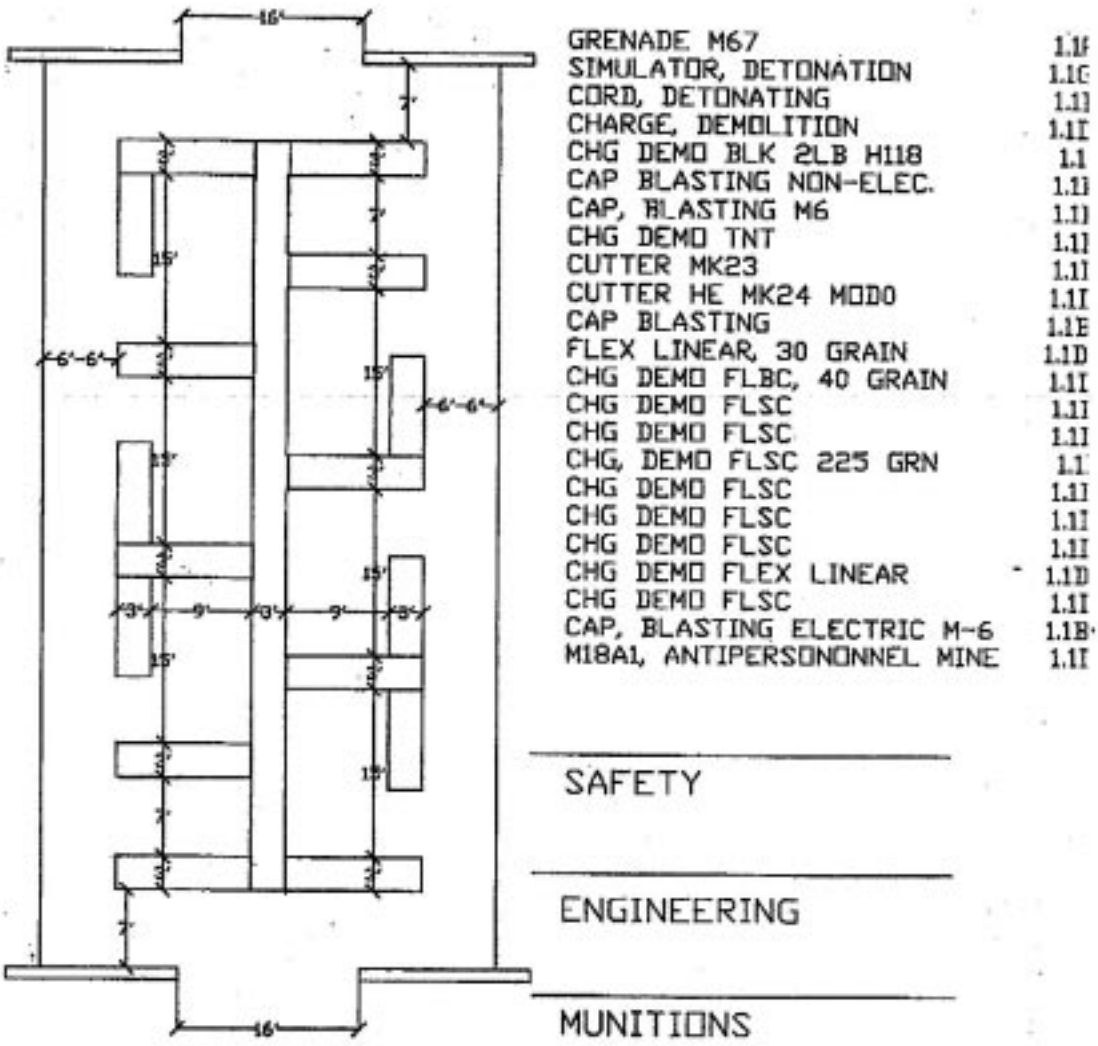


FIG. 1. PLAN VIEW OF CELL WALLS IN IGLOO MAGAZINE

NOT TO SCALE

ANG-DWG-96-001